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Hwang et al.

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(54) **OVERLAY ELECTROMAGNETIC BANDGAP (EBG) STRUCTURE AND METHOD OF MANUFACTURING THE SAME**

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(*) Notice: Subject to any disclaimer, the term of this patent is extended or adjusted under 35 U.S.C. 154(b) by 277 days.

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(30) **Foreign Application Priority Data**

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(51) **Int. Cl.**
H01P 1/203 (2006.01)

(52) **U.S. Cl.** **333/205**

(58) **Field of Classification Search** 333/167, 333/168, 175, 185, 202, 204, 205, 238
See application file for complete search history.

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(57) **ABSTRACT**

Provided is an electromagnetic bandgap (EBG) structure, and particularly, an overlay EBG structure in which a plurality of vias and a plurality of plates are formed at intervals on a central signal line in such a manner that the vias and plates extend vertically from a substrate in order to reduce leakage loss of an electromagnetic wave through the substrate. Therefore, it is possible to prevent an electromagnetic wave passing through a transmission line from being lost through the substrate, to obtain desired frequency characteristics by adjusting the dimensions of the vias and plates, and to manufacture the overlay EBG structure using an existing CMOS process without having to perform any additional process.

17 Claims, 8 Drawing Sheets

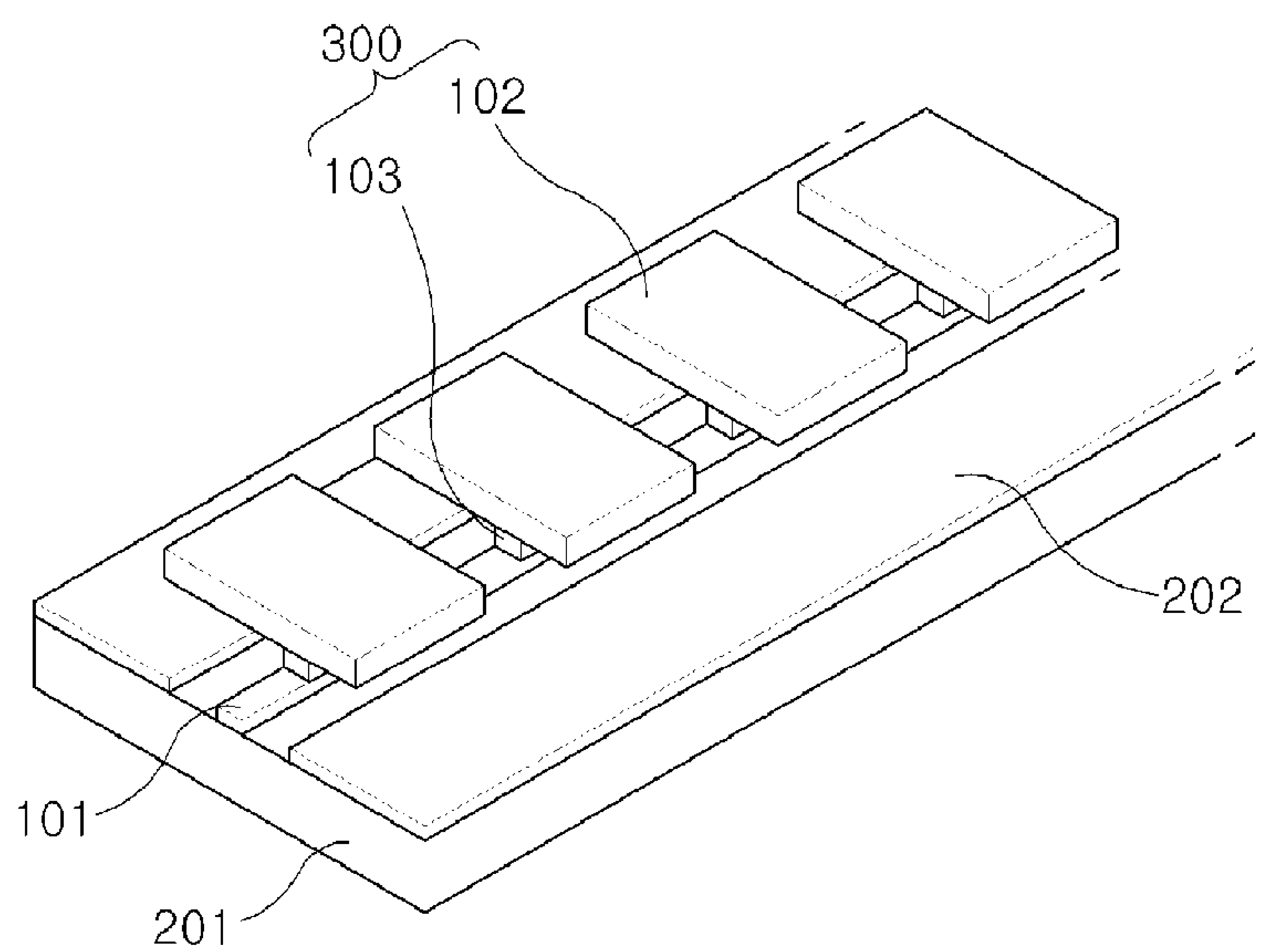


FIG.1

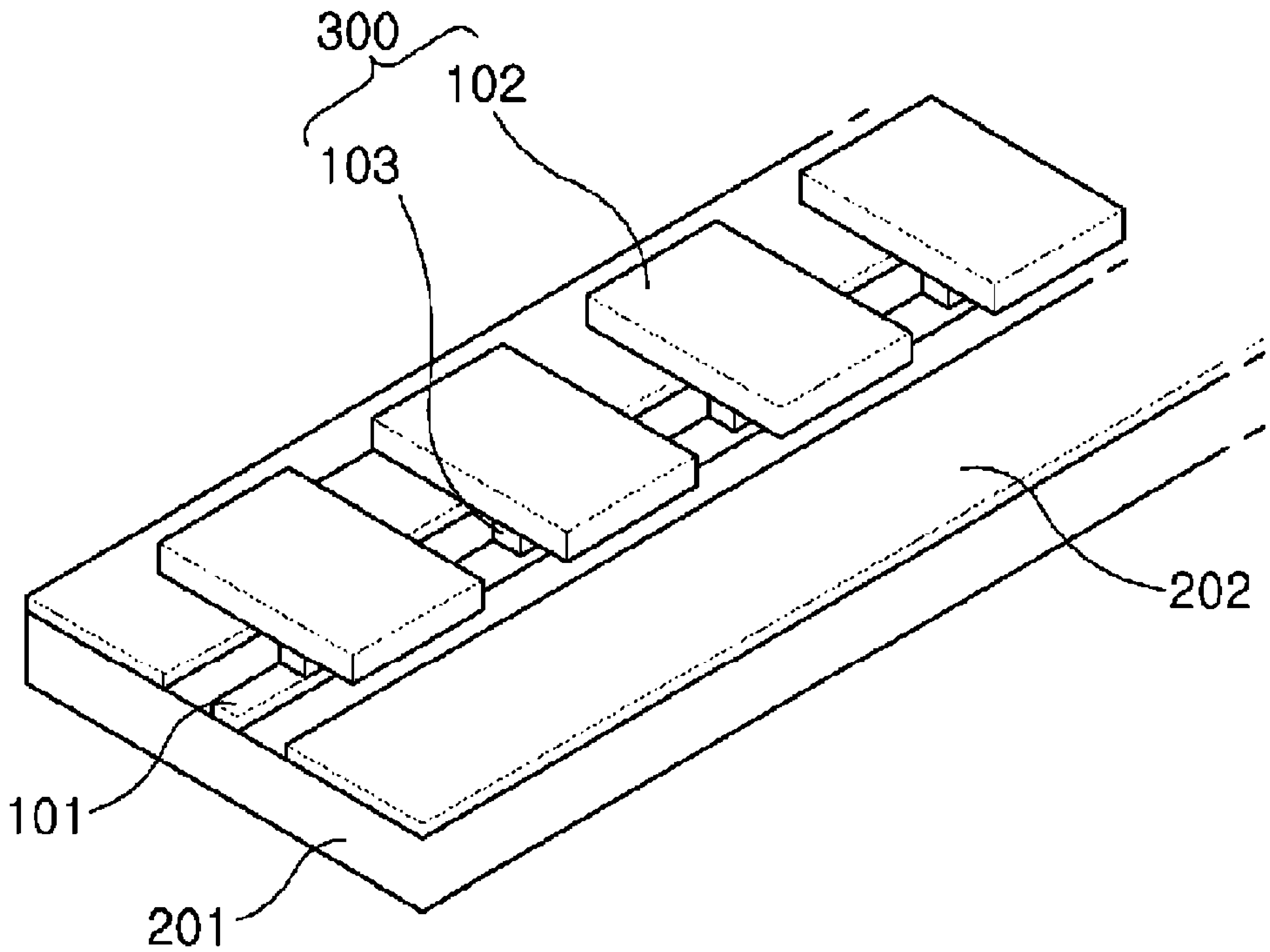


FIG.2

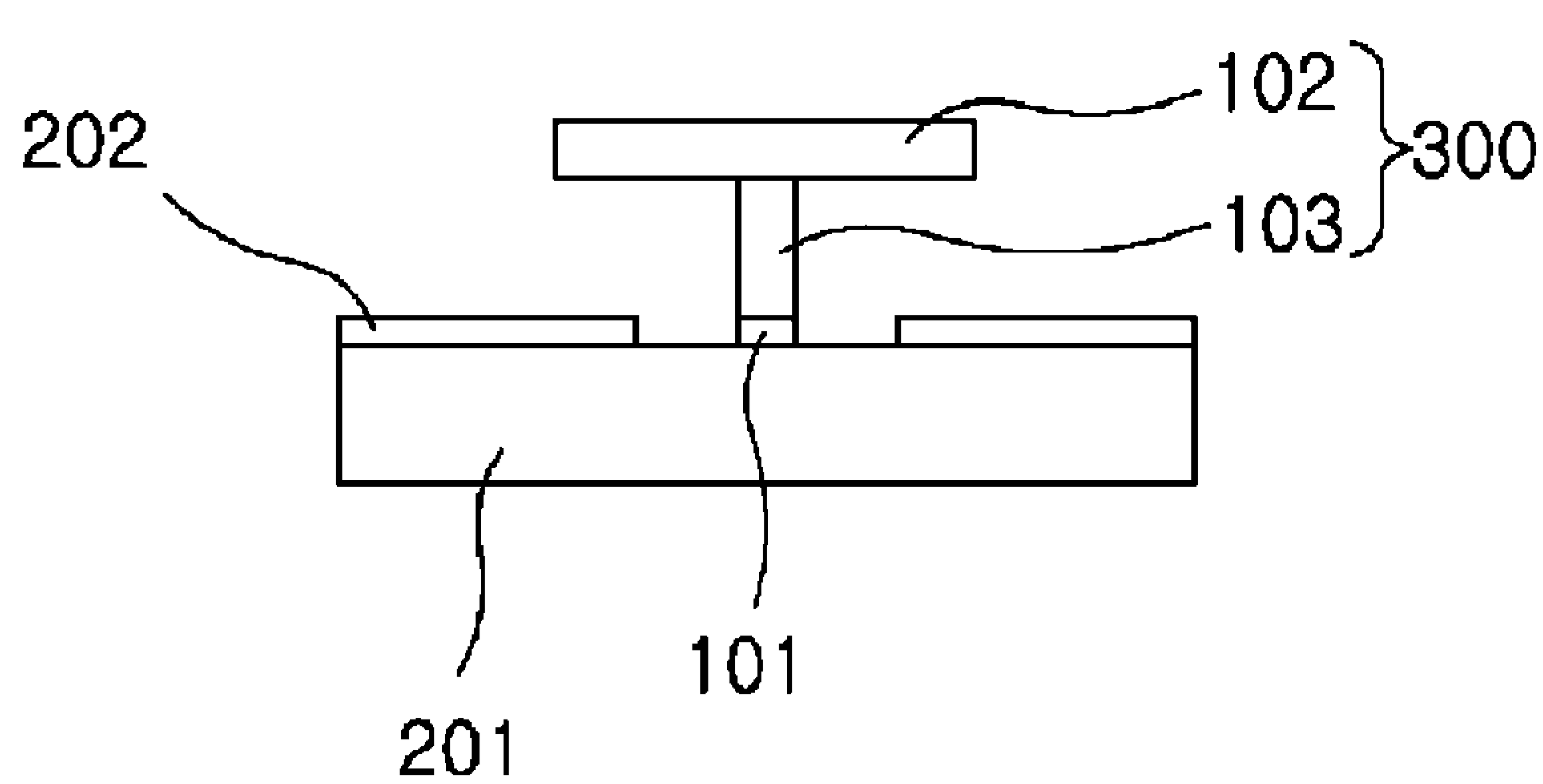


FIG.3

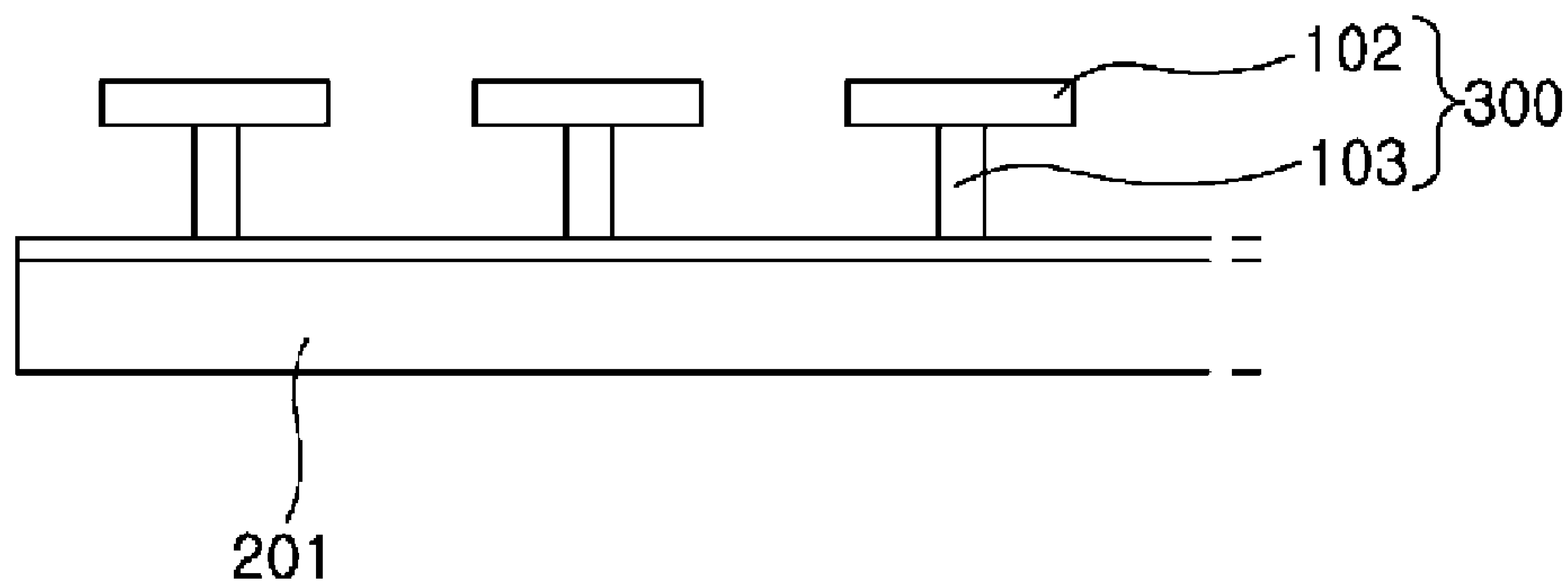


FIG.4

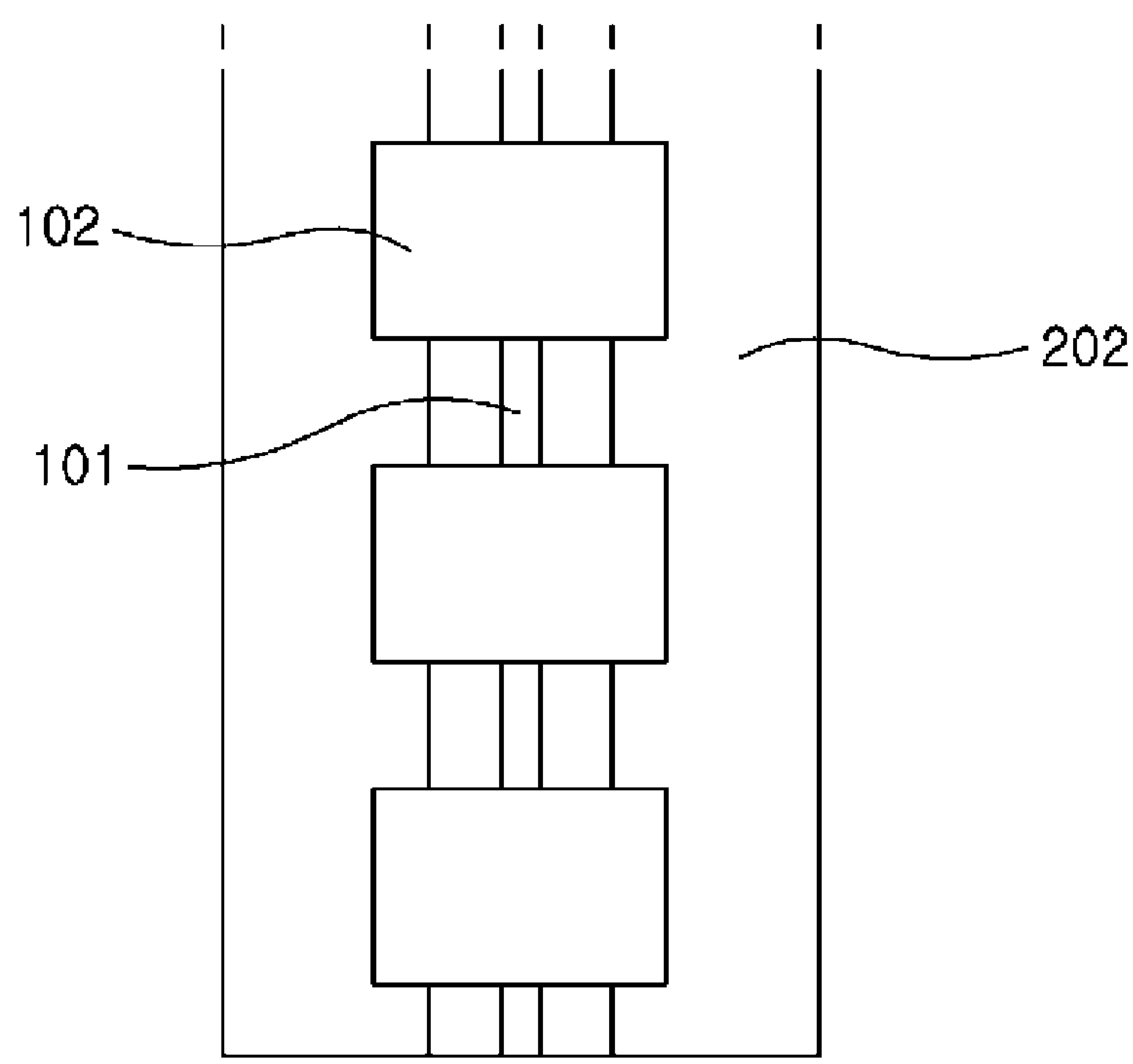


FIG.5

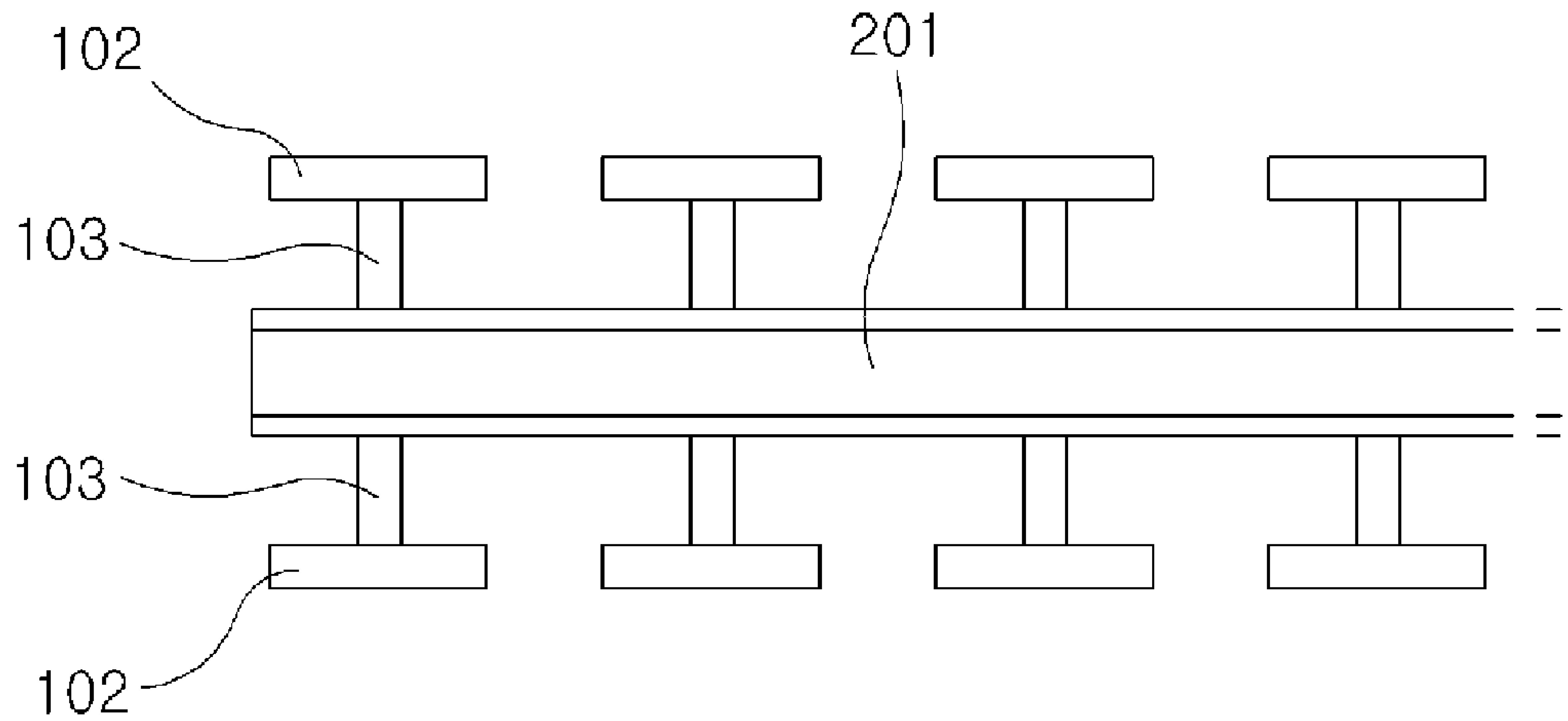


FIG.6

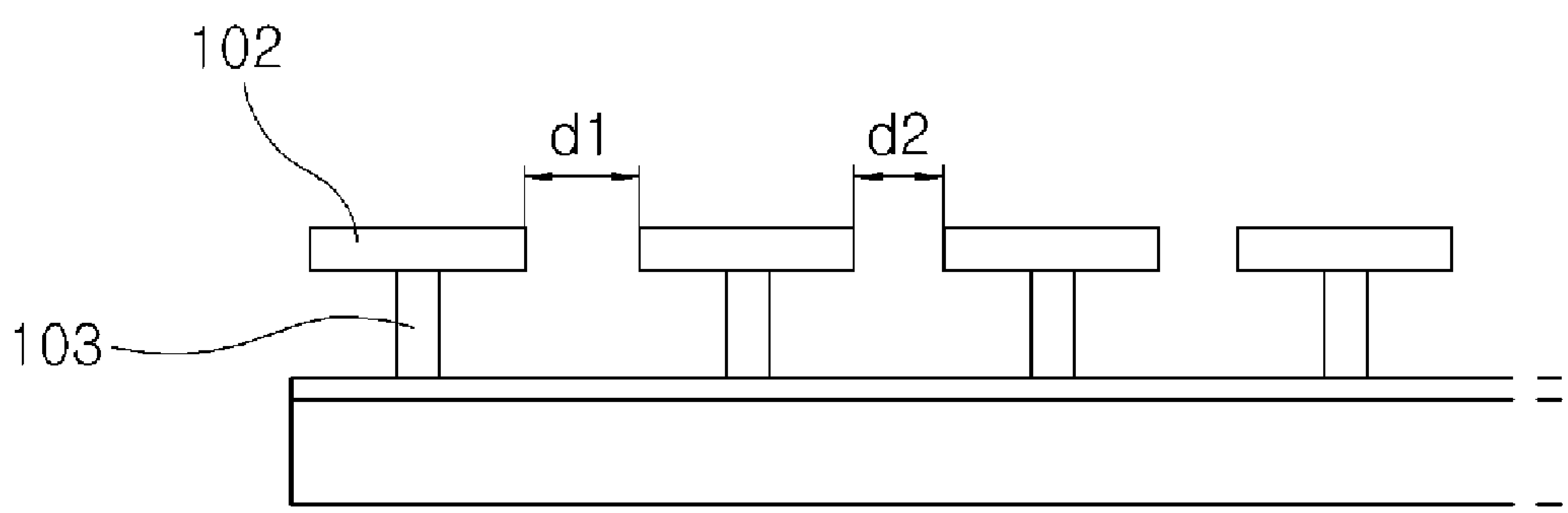


FIG.7

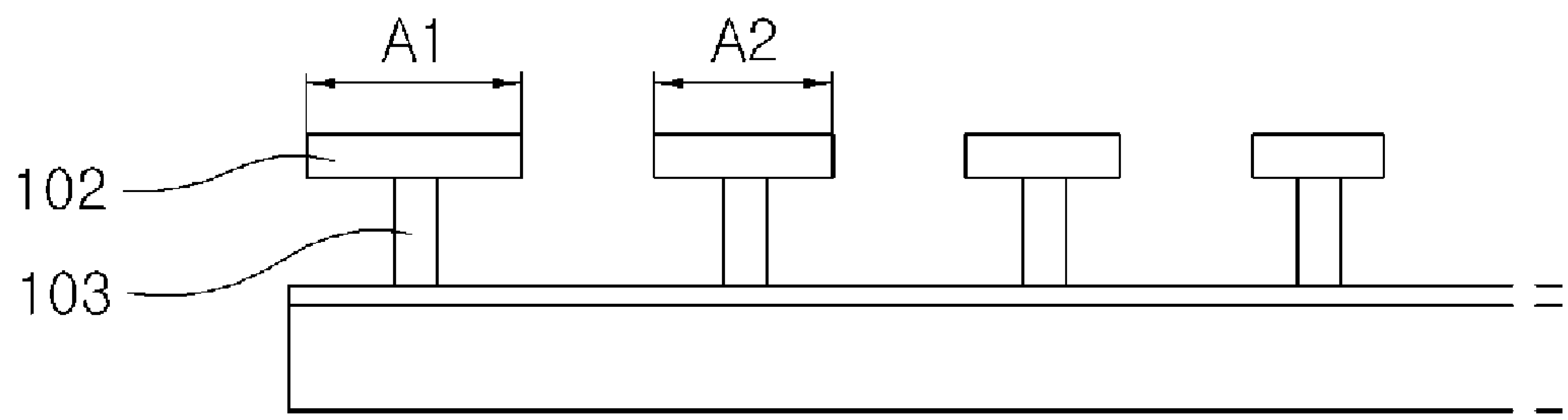


FIG.8

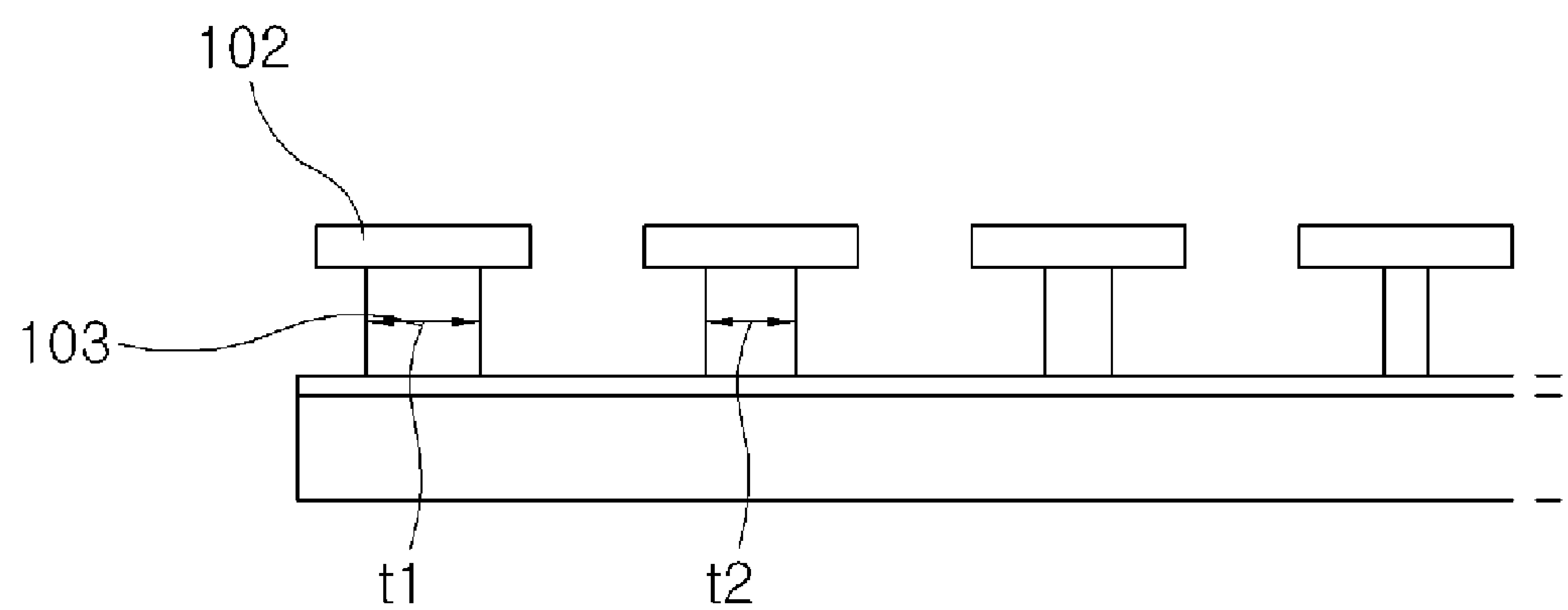


FIG.9

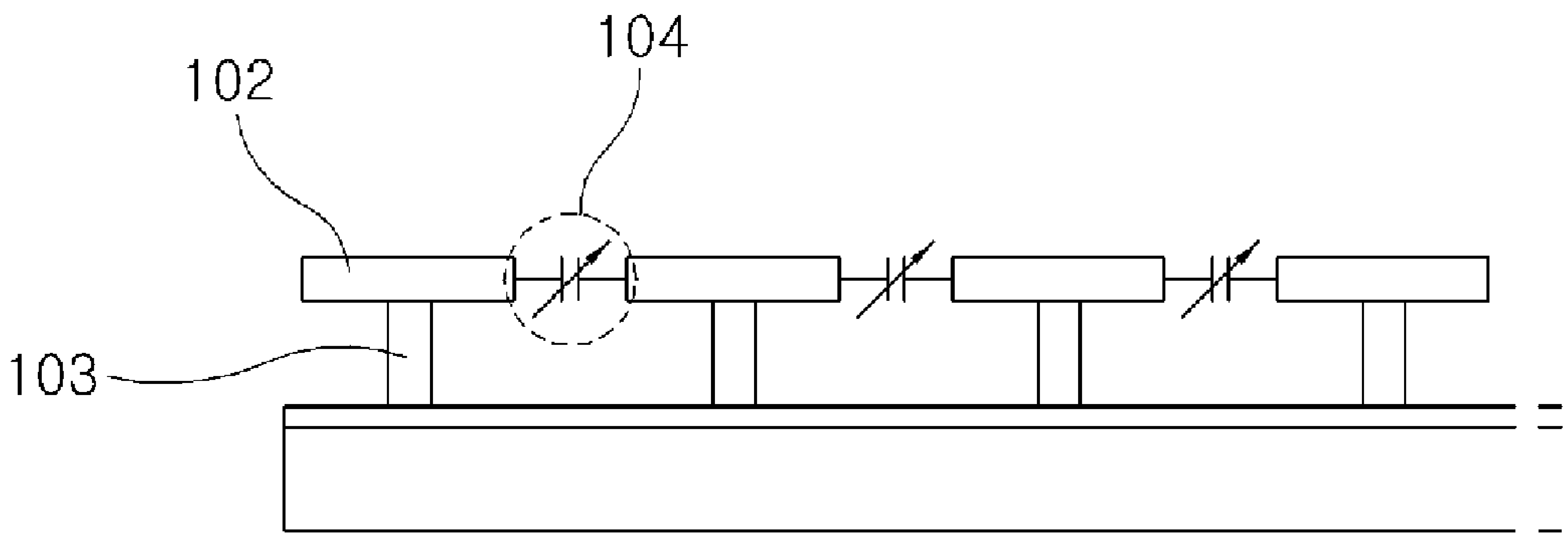


FIG.10

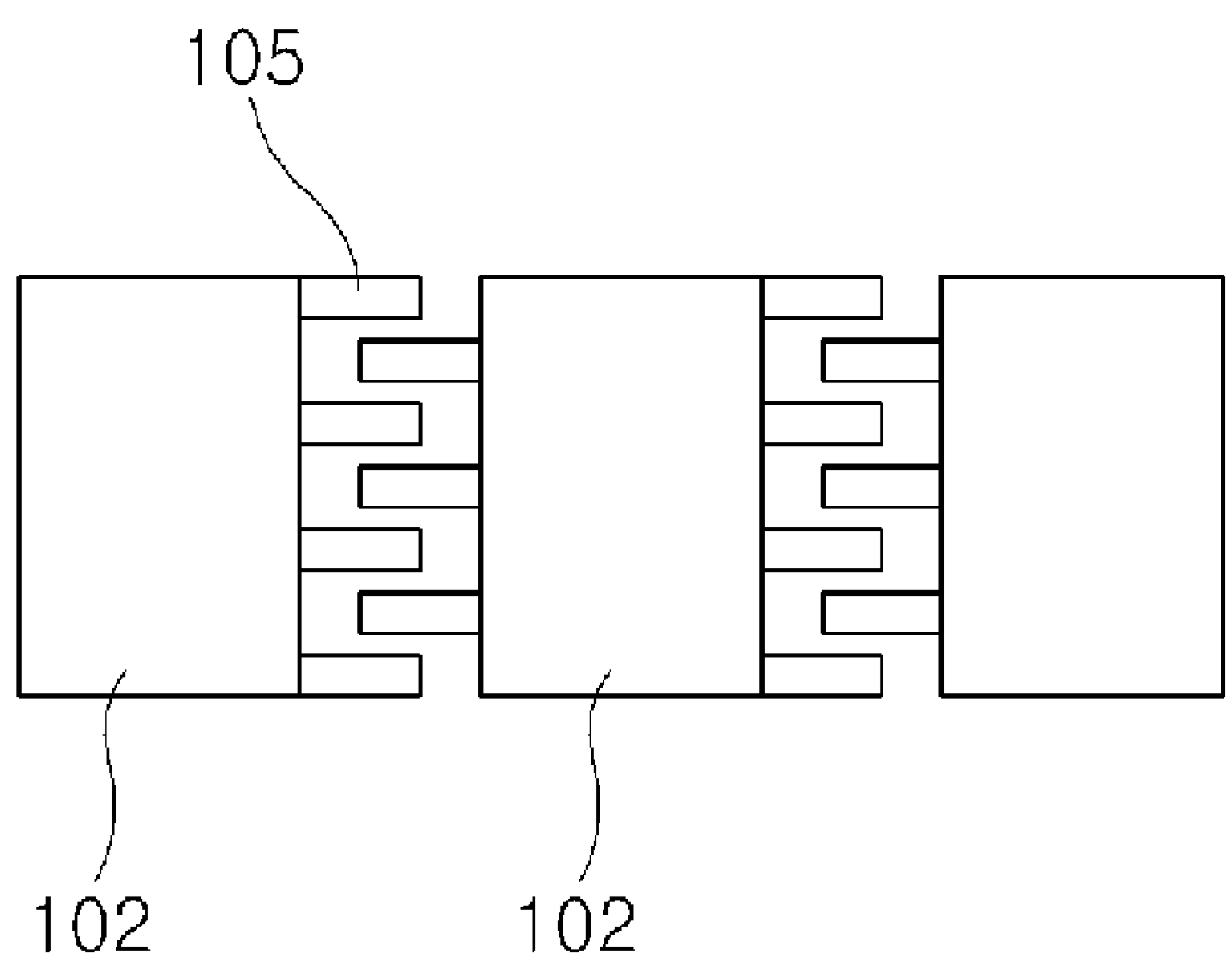


FIG.11

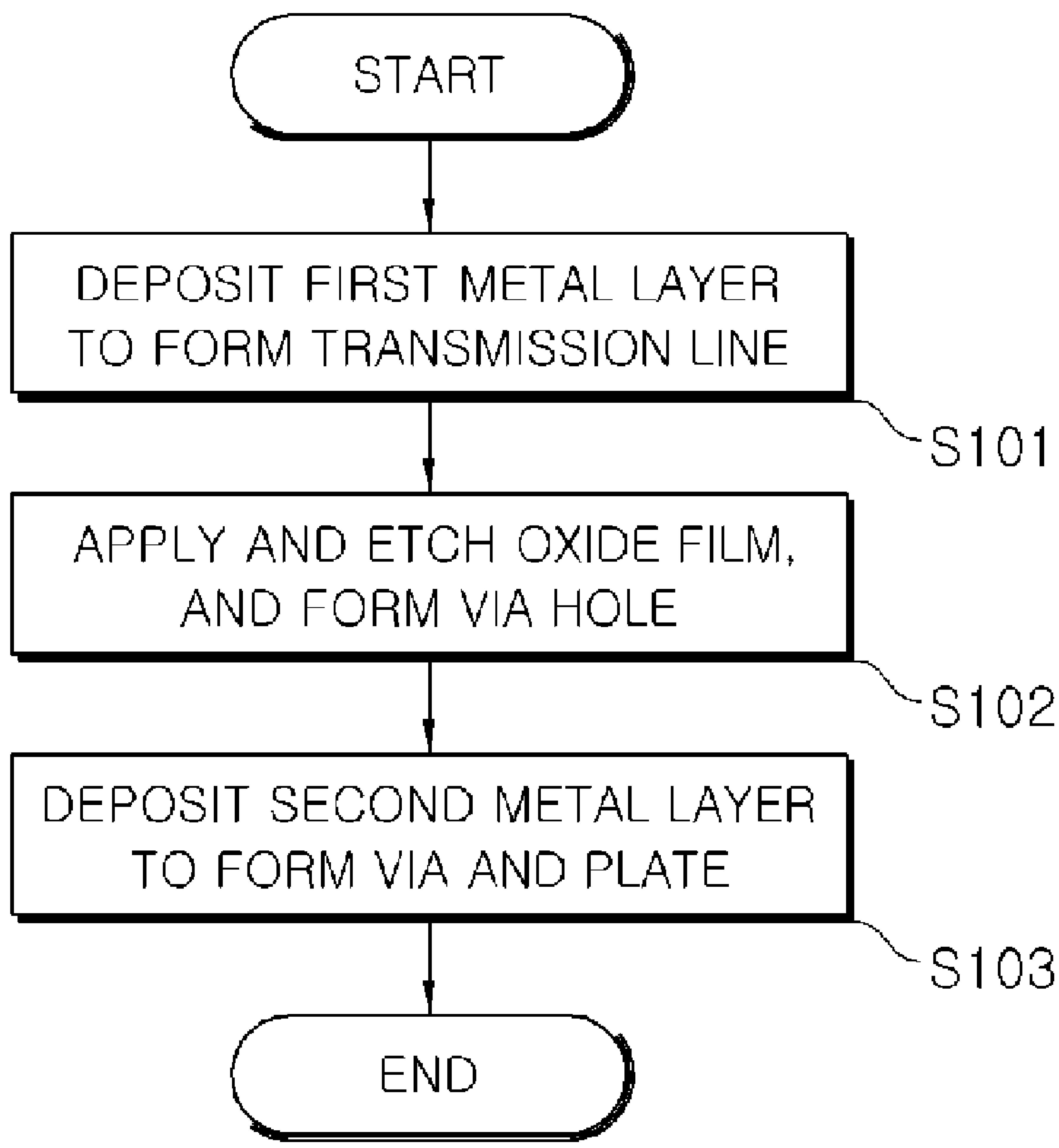

START
DEPOSIT FIRST METAL LAYER TO FORM TRANSMISSION LINE
S101
APPLY AND ETCH OXIDE FILM, AND FORM VIA HOLE
S102
DEPOSIT SECOND METAL LAYER TO FORM VIA AND PLATE
S103
END

FIG.12A

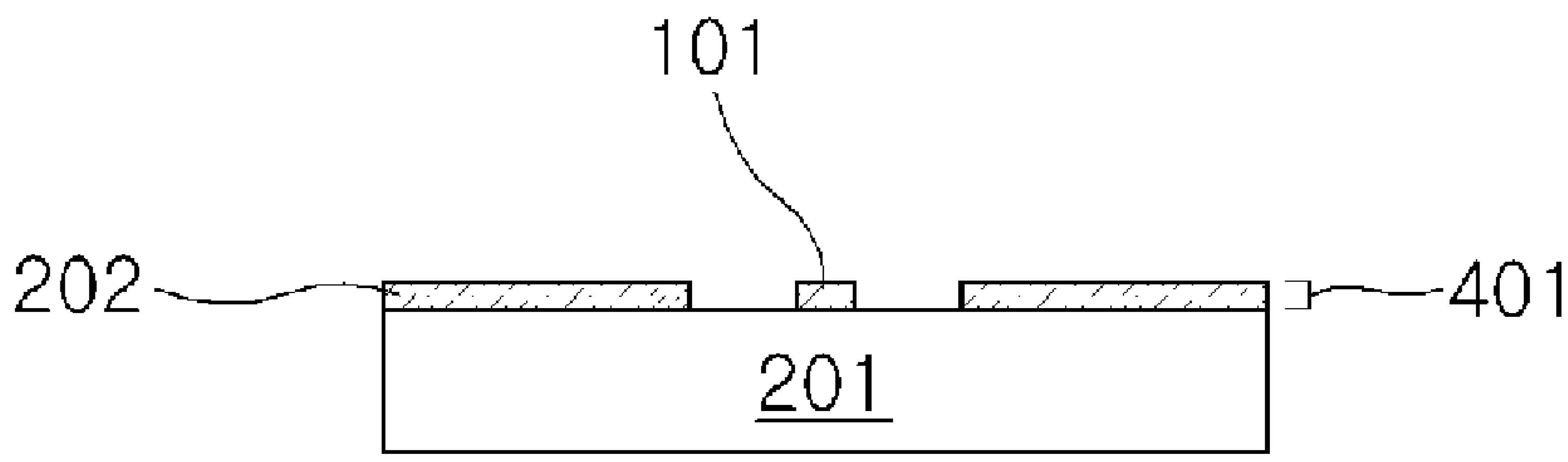


FIG.12B

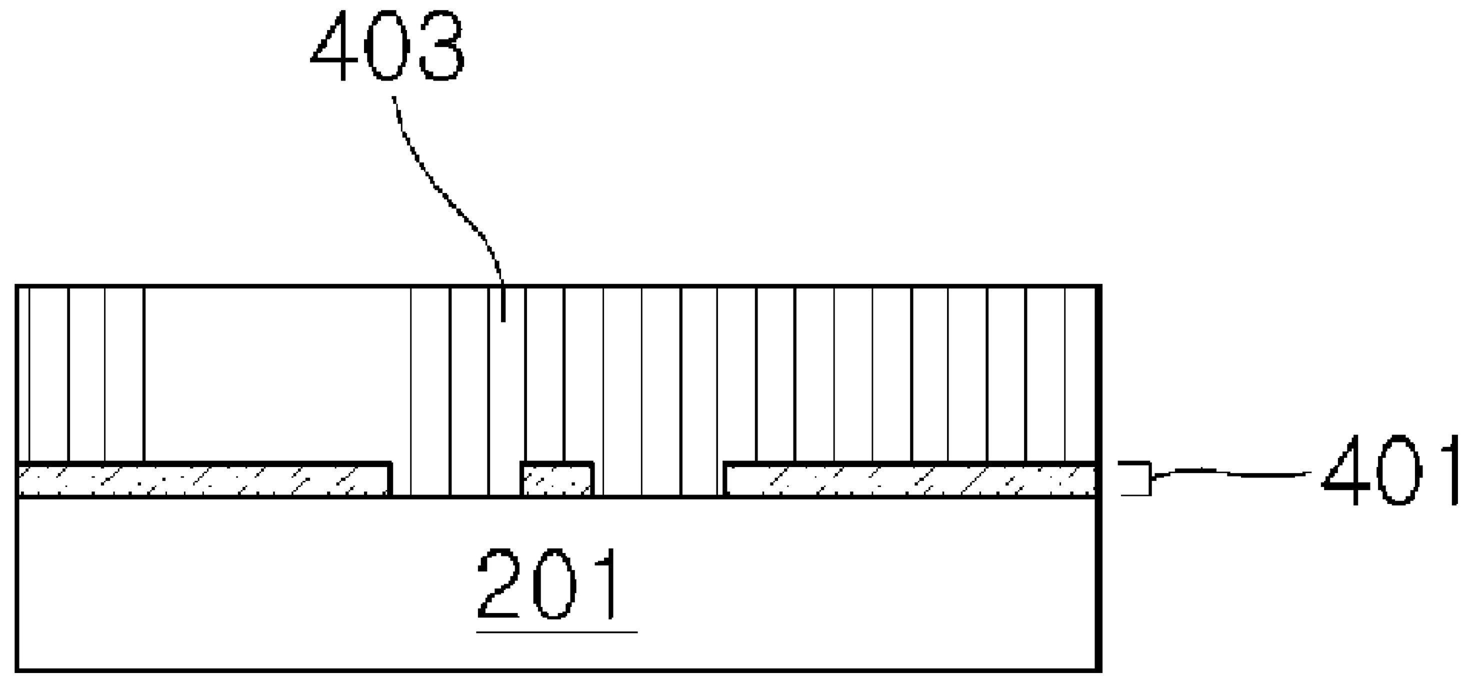


FIG.12C

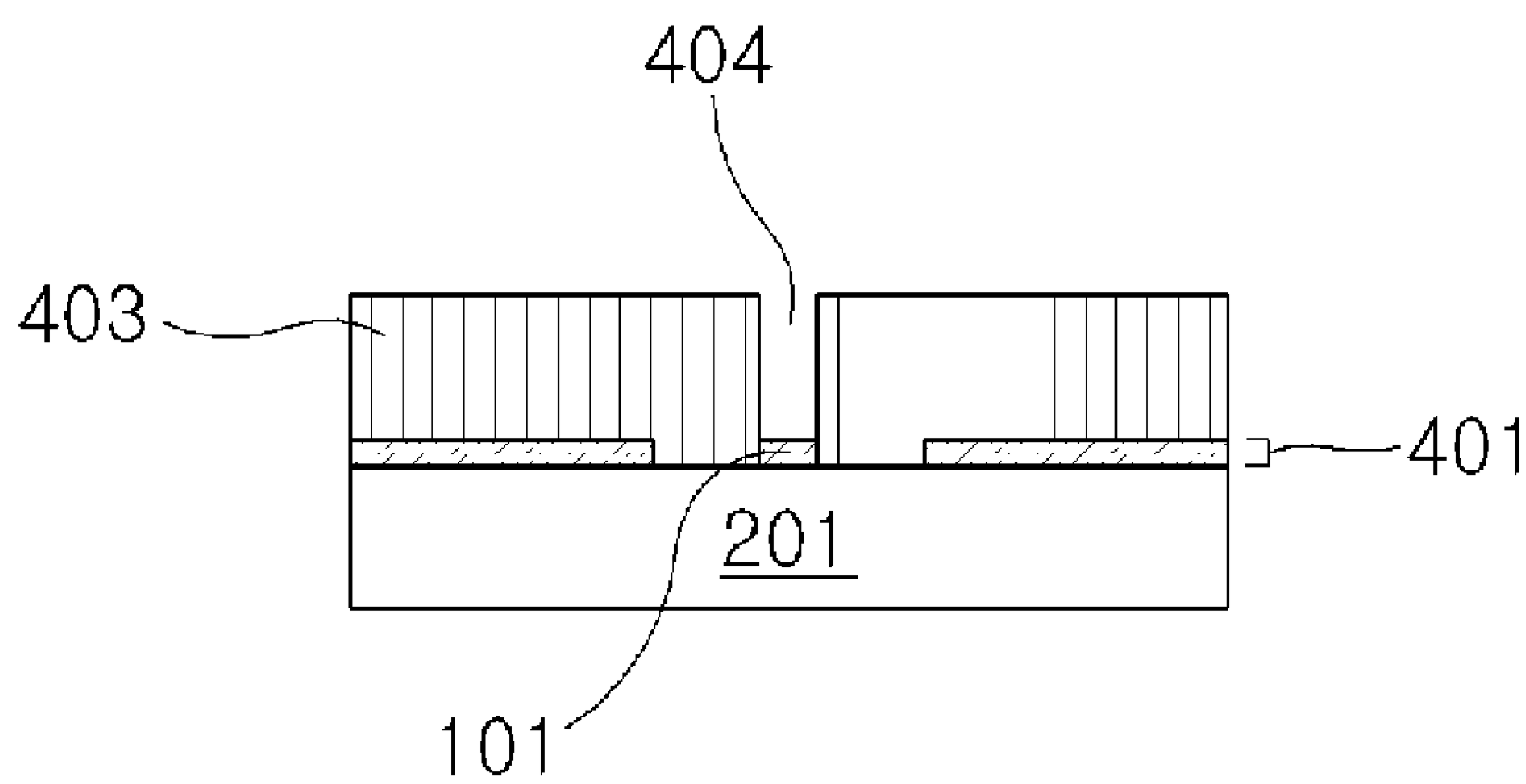
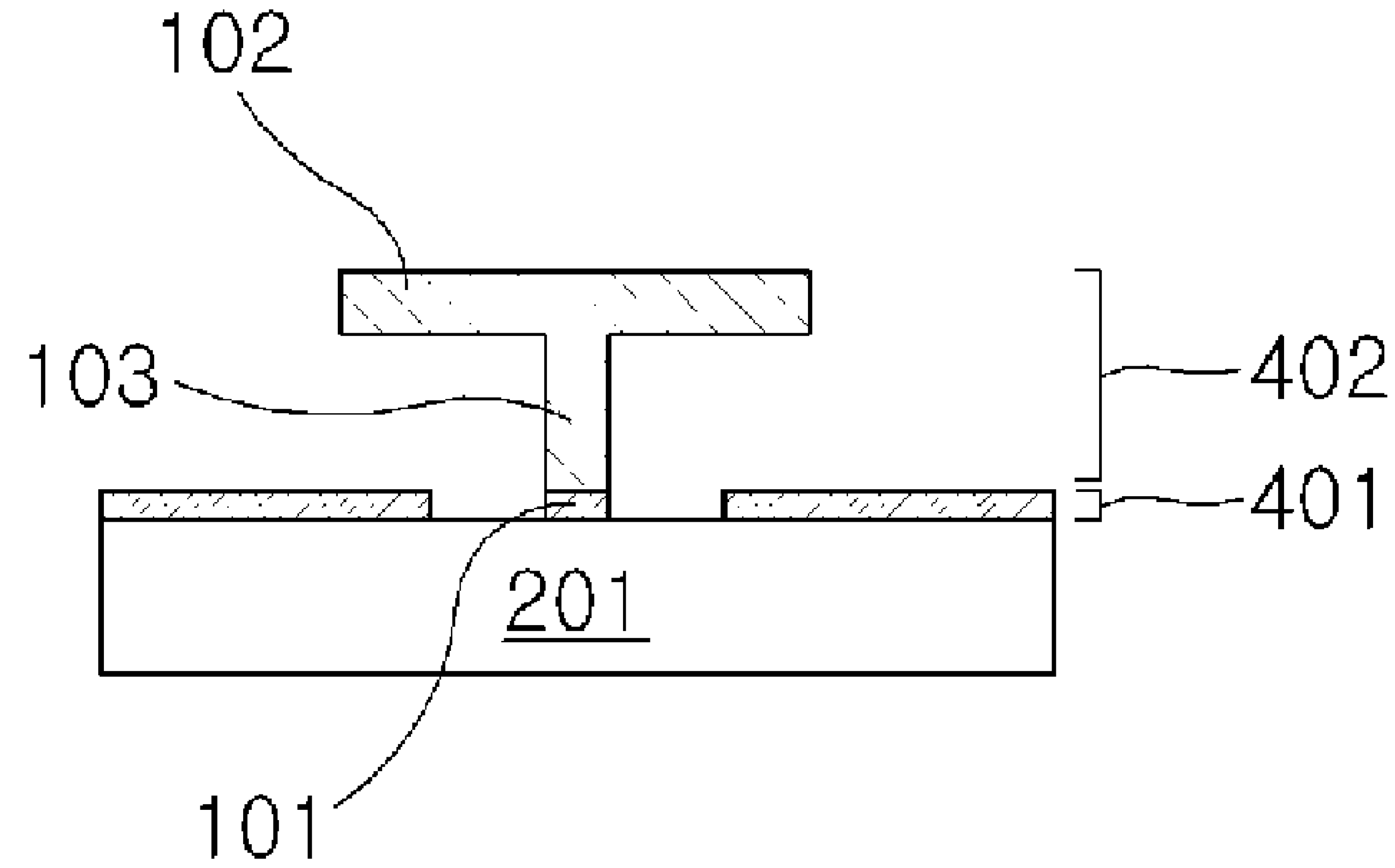


FIG.12D



OVERLAY ELECTROMAGNETIC BANDGAP (EBG) STRUCTURE AND METHOD OF MANUFACTURING THE SAME

CROSS REFERENCE TO RELATED APPLICATIONS

This application claims priority from Korean Patent Application No. 10-2007-0102266, filed on Oct. 10, 2007, the disclosure of which is incorporated herein in its entirety by reference.

BACKGROUND OF THE INVENTION

1. Field of the Invention

The present invention relates to an Electromagnetic Bandgap (EBG) structure, and more particularly, to an overlay Electromagnetic Bandgap (EBG) structure for reducing leakage loss of an electromagnetic wave through a substrate, and a method of manufacturing the same.

2. Description of the Related Art

With the development of information communication technologies, various communication devices have been developed and distributed. Also, to increase the number of communication channels and reduce the size of communication systems, various communication devices using high-band frequencies are being developed. Such communication devices essentially have a function of selecting or controlling a specific frequency. In general, a circuit for selecting or controlling a specific frequency is implemented by arranging lumped-type passive elements (for example, inductors or capacitors).

However, when a high frequency is used, a wavelength is shortened, and accordingly interference between communication lines becomes significant, so that each communication line operates as a circuit element. That is, since the number of unexpected components increase in a high frequency environment, a problem may occur when general passive elements are used in a microwave band (or in a millimeter wave band).

For this reason, research into developing passive elements capable of being used in a super high frequency band has been carried out. For example, a trial has been conducted to arrange existing lumped elements on the same plane to predict parasitic components in a high frequency environment. A remarkable structure is an electromagnetic bandgap (EBG) structure in which a photonic bandgap (PBG) structure for guiding photons is applied to a super high frequency area. The EBG structure is applied to various devices, such as a filter, a resonator, etc.

However, an existing EBG structure causes additional leakage loss of an electromagnetic wave through a substrate when a PBG is integrated into a flat integrated circuit, and the leakage loss deteriorates a band selection characteristic of a filter.

SUMMARY OF THE INVENTION

The present invention provides an Electromagnetic Bandgap (EBG) structure which can reduce leakage loss of an electromagnetic wave through a substrate and easily adjust frequency characteristics, and a method of manufacturing the same.

The EBG structure according to the present invention is implemented by providing an overlay EBG structure in which a plurality of vias and a plurality of plates are aligned at intervals on a central signal line of a substrate, and a manufacturing method thereof.

According to an aspect of the present invention, there is provided an overlay electromagnetic bandgap (EBG) structure including: a transmission line formed on a substrate, and transmitting a signal; a plurality of plates, each plate formed over and separated from the transmission line; and a plurality of vias, each via connecting a plate to the transmission line, wherein the plates and the vias are formed at predetermined intervals in a longitudinal direction of the transmission line.

Also, frequency characteristics of the overlay EBG structure are controlled by properly adjusting a dimension of the via or the plate. For example, the frequency characteristics of the overlay EBG structure are controlled by properly adjusting intervals between plates, dimensions of the plates, shapes of the plates, intervals between vias, thicknesses of the vias, etc.

The overlay EGB structure further includes a plurality of varactors respectively inserted between the plurality of plates, wherein frequency characteristics of the overlay EGB structure are controlled by the plurality of varactors.

Also, the overlay EBG structure is formed on both a front surface and a rear surface of the substrate.

According to an aspect of the present invention, there is provided a method of manufacturing an overlay electromagnetic bandgap (EBG) structure, including: depositing a first metal layer on a substrate to form a transmission line; applying an oxide film on the substrate and etching the oxide film to form a via hole for exposing the transmission line; and depositing a second metal line through the via hole to form a via extended from the transmission line and a plate connected to one end of the via.

The via and the plate are formed at predetermined intervals in a longitudinal direction of the transmission line.

Additional aspects of the invention will be set forth in the description which follows, and in part will be apparent from the description, or may be learned by practice of the invention.

It is to be understood that both the foregoing general description and the following detailed description are exemplary and explanatory and are intended to provide further explanation of the invention as claimed.

BRIEF DESCRIPTION OF THE DRAWINGS

The accompanying drawings, which are included to provide a further understanding of the invention and are incorporated in and constitute a part of this specification, illustrate exemplary embodiments of the invention, and together with the description serve to explain the aspects of the invention.

FIG. **1** is a perspective view of an overlay Electromagnetic Bandgap (EBG) structure according to an embodiment of the present invention;

FIG. **2** is a front cross-sectional view of the overlay EBG structure illustrated in FIG. **1**;

FIG. **3** is a side cross-sectional view of the overlay EBG structure illustrated in FIG. **1**;

FIG. **4** is a plan view of the overlay EBG structure illustrated in FIG. **1**;

FIG. **5** illustrates a structure where two of the overlay EBG structures illustrated in FIG. **1** are coupled vertically, according to an embodiment of the present invention;

FIG. **6** illustrates an overlay EBG structure in which a plurality of plates are aligned at irregular intervals, according to another embodiment of the present invention;

FIG. **7** illustrates an overlay EBG structure in which a plurality of plates having different sizes are aligned, according to another embodiment of the present invention;

FIG. **8** illustrates an overlay EBG structure in which a plurality of vias having different thicknesses are aligned, according to another embodiment of the present invention;

FIG. **9** illustrates an overlay EBG structure in which varactors are respectively inserted between plates, according to another embodiment of the present invention;

FIG. **10** illustrates an overlay EBG structure in which a plurality of plates having lattice shapes are aligned, according to another embodiment of the present invention;

FIG. **11** is a flowchart of a method of manufacturing an overlay EBG structure, according to an embodiment to the present invention; and

FIGS. **12**A through **12**D are exemplary views for explaining the overlay EBG structure manufacturing method illustrated in FIG. **11**.

DETAILED DESCRIPTION OF EXEMPLARY EMBODIMENTS

The invention is described more fully hereinafter with reference to the accompanying drawings, in which exemplary embodiments of the invention are shown. This invention may, however, be embodied in many different forms and should not be construed as limited to the exemplary embodiments set forth herein. Rather, these exemplary embodiments are provided so that this disclosure is thorough, and will fully convey the scope of the invention to those skilled in the art. In the drawings, the size and relative sizes of layers and regions may be exaggerated for clarity. Like reference numerals in the drawings denote like elements.

FIG. **1** is a perspective view of an overlay Electromagnetic Bandgap (EBG) structure according to an embodiment of the present invention, FIG. **2** is a front cross-sectional view of the overlay EBG structure illustrated in FIG. **1**, FIG. **3** is a side cross-sectional view of the overlay EBG structure illustrated in FIG. **1**, and FIG. **4** is a plan view of the overlay EBG structure illustrated in FIG. **1**.

Referring to FIGS. **1** through **4**, the overlay EBG structure includes a transmission line **101**, a plurality of plates **102**, and a plurality of vias **103**.

The transmission line **101** is formed on the substrate **201** and transmits signals. A signal passing through the transmission line **101** may be an electromagnetic wave having a high frequency. Also, the transmission line **101** may be a central signal line of a coplanar waveguide (CPW).

The plurality of plates **102** are formed over and separated from the transmission line **101**. Each plate **102** may be a rectangle or a thin film, and is separated from the transmission line **101** and a ground plate **202**. A portion of the plate **102** may face the ground plate **202** so that capacitance is formed between the plate **102** and the ground plate **202**. Also, the plate **102** is made of the same material as that of the transmission line **101** so a signal can pass therethrough.

Each via **103** connects each plate **102** to the transmission line **101**. That is, a via **103** is extended vertically from the transmission line **101** in such a manner that one end of the via **103** is connected to the center portion of the plate **102**. The via **103** is made of the same material as that of the transmission line **101**. Accordingly, the via **103** connects the transmission line **101** to the plate **102** so that signals can be transmitted between the transmission line **101** and the plate **102**.

In an existing coplanar waveguide (CPW) structure, since an electric field for inducing electromagnetic waves is generated between a transmission line and a ground plate, there is a problem in that some of the electrical field is lost through the substrate **201**. However, in the overlay EBG structure according to this embodiment of the present invention, since a major part of an electric field is generated vertically between the plate **102** and the ground plate **202**, leakage loss through a substrate is reduced. Also, in order to apply the advantage of the overlay EBG structure to an existing EBG structure, the plate **102** and the via **103** form a single unit **300**, and a plurality of units **300** are aligned at predetermined intervals in a longitudinal direction of the transmission line **101**. Here, the plurality of units **300** may be aligned at regular or irregular intervals.

Furthermore, the dimensions (for example, intervals, sizes, thicknesses, etc.) of the units **300** can vary, and the overlay EBG structure according to the present invention can be used as a filter by properly adjusting the dimensions of the units **300**. In this case, the frequency characteristics of the filter can be controlled by adjusting the dimensions of the plates **102** or vias **103**.

In the existing EBG structure, since predetermined cavities for setting frequency characteristics are arranged at regular intervals on a plane, an additional space for the cavities should be prepared. However, in the current embodiment of the present invention, since the units **300** are arranged vertically from the substrate **201**, an additional space for the cavities can be reduced. In particular, as illustrated in FIG. **5**, two overlay EBG structures respectively having plates **102** and vias **103** aligned therein may be coupled vertically with a substrate **201** in between.

FIG. **6** illustrates an overlay EBG structure in which a plurality of plates **102** are aligned at irregular intervals, according to another embodiment of the present invention. The overlay EBG structure illustrated in FIG. **6** can be applied to a filter.

Referring to FIG. **6**, the plurality of plates **102**, each connected to one end of a via **103**, are aligned at irregular intervals (for example, $d_1 \neq d_2$). Since the frequency characteristics of the overlay EBG structure vary when the intervals between the plates **102** vary, frequency tuning is possible by varying the intervals between the plates **102**. Also, in order to vary the intervals between the plates **102**, intervals between vias **103** can be properly adjusted.

FIG. **7** illustrates an overlay EBG structure in which a plurality of plates **102** having different sizes are aligned, according to another embodiment of the present invention. The overlay EBG structure illustrated in FIG. **7** can also be applied to a filter.

Referring to FIG. **7**, the plurality of plates **102**, each connected to one end of a via **103**, have different sizes (for example, $A_1 \neq A_2$). Since the frequency characteristics of the overlay EBG structure vary when the plates **102** have different sizes, frequency tuning is possible by varying the sizes of the plates **102**.

FIG. **8** illustrates an overlay EBG structure in which a plurality of vias **103** having different thicknesses are aligned, according to another embodiment of the present invention. The overlay EBG structure illustrated in FIG. **8** can also be applied to a filter.

Referring to FIG. **8**, the plurality of vias **103**, whose one end is connected to a plate **102**, have different thicknesses (for example, $t1 \neq t2$). Here, the thickness of the via **103** means a cross-section of the via **103**. As described above, since the frequency characteristics of the overlay EBG structure vary when the thickness of the via **103** varies, frequency tuning is possible by varying the thicknesses of the vias **103**.

FIG. **9** illustrates an overlay EBG structure in which varactors **104** are respectively inserted between plates **102**, according to another embodiment of the present invention.

In FIG. **9**, the varactors **104** are respectively inserted between the plates **102** which are arranged at intervals. The varactors **104** may be elements (for example, variable capacitance diodes) whose electrostatic fields change according to a voltage applied thereto. Accordingly, since capacitances between the plates **102** are changed by the varactors **104**, it is possible to adjust the frequency characteristics of the overlay EBG structure using the varactors **104**.

FIG. **10** illustrates an overlay EBG structure in which a plurality of plates **102** having saw-toothed shapes are aligned, according to another embodiment of the present invention.

Referring to FIG. **10**, the facing sides of neighboring plates **102** are formed in an interdigital structure. Here, "interdigital structure" means that a plurality of projection parts are formed in at least one side of each plate **102**, and the projection parts of the facing sides of neighboring plates **102** mesh with each other. Since capacitance between the plates **102** varies when the shapes of the plates **102** vary, the frequency characteristics of the overlay EBG structure can be controlled by varying the shape of the plates **102**.

As illustrated in FIGS. **6** through **10**, the overlay EBG structures according to the embodiments of the present invention can control frequency characteristics by adjusting the dimensions of the units **300** including the plates **102** and the vias **103**. Accordingly, the overlay EBG structures can be used as a band stop filter (BSF) which suppresses a specific frequency band, however, the present invention is not limited to this.

Hereinafter, a method of manufacturing an overlay EBG structure according to an embodiment of the present invention, will be described with reference to FIGS. **11** and **12**A through **12**D. The overlay EBG structure manufacturing method is based on a conventional complementary metal-oxide semiconductor (CMOS) manufacturing process, and details for the CMOS manufacturing process will be omitted.

In operation S**101**, a first metal layer **401** is deposited on a substrate **201** to form a transmission line **101** (see FIG. **12**A). At this time, ground plates **202** can be formed on the substrate **201** in such a manner that the ground plates **202** are separated from each other with the transmission line **101** in between.

In operation S**102**, an oxide film **403** is applied on the substrate **201**, and etched so that a via hole **404** is formed to expose the transmission line **101** (see FIGS. **12**B and **12**C). In detail, a via mask is placed on the oxide film **403** and patterned, thereby forming the via hole **404**. The via hole **404** is used to form a via **103** that is to be connected to the transmission line **101**.

In operation S**103**, a second metal layer **402** is deposited through the via hole **404** to form a via **103** and a plate **102** (see FIG. **12**D). That is, the second metal layer **402** is connected to the transmission line **101** through the via hole **404** to form a via **103** and a plate **102**. Here, the via **103** and the plate **102** can be formed at predetermined intervals in a longitudinal direction of the transmission line **101**.

In FIG. **12**D, the oxide film **403** is removed in order to clearly show the structure according to the current embodiment, but, the oxide film **403** may not be removed.

In this manner, the via **103** and the plate **102**, which are extended from the transmission line **10**, are formed at predetermined intervals, so that an overlay EBG structure is complete.

As a result, in the overlay EBG structure and the manufacturing method thereof, according to the present invention, as described above, since the vias and plates extend vertically from the transmission line and from the substrate, it is possible to prevent an electromagnetic wave passing through the transmission line from being lost through the substrate, to obtain desired frequency characteristics by adjusting the dimensions of the vias and plates, and to manufacture the overlay EBG structure using an existing CMOS process without having to perform any additional process.

It will be apparent to those skilled in the art that various modifications and variations can be made in the present invention without departing from the spirit or scope of the invention. Thus, it is intended that the present invention covers the modifications and variations of this invention provided they come within the scope of the appended claims and their equivalents.

What is claimed is:

1. An overlay electromagnetic bandgap (EBG) structure comprising:

a transmission line which is formed on a substrate, and transmits a signal;

a plurality of plates, each of the plurality of plates is formed over and separated from the transmission line; and

a plurality of vias, each of the plurality of vias connects a respective plate of the plurality of plates to the transmission line,

wherein the plurality of plates and the plurality of vias are formed at predetermined intervals in a longitudinal direction of the transmission line.

2. The overlay EBG structure of claim **1**, wherein frequency characteristics of the overlay EBG structure are controlled by adjusting the predetermined intervals between the plurality of plates.

3. The overlay EGB structure of claim **1**, wherein frequency characteristics of the overlay EBG structure are controlled by adjusting sizes of the plurality of plates.

4. The overlay EGB structure of claim **1**, wherein frequency characteristics of the overlay EBG structure are controlled by adjusting thicknesses of the plurality of vias.

5. The overlay EGB structure of claim **1**, further comprising a plurality of varactors respectively inserted between the plurality of plates,

wherein frequency characteristics of the overlay EGB structure are controlled by the plurality of varactors.

6. The overlay EBG structure of claim **1**, wherein facing sides of the plurality of plates are formed in an interdigital structure, and mesh with each other.

7. The overlay EBG structure of claim **1**, formed on both a front surface and a rear surface of the substrate.

8. The overlay EBG structure of claim **1**, wherein the transmission line is a central signal line of a coplanar waveguide (CPW).

9. The overlay EBG structure of claim **1**, wherein the transmission line and the plurality of plates are disposed above the substrate on a same side of the substrate.

10. The overlay EBG structure of claim **1**, further comprising first and second ground plates extending in the longitudinal direction and disposed on a same side of the substrate as the transmission line such that the transmission line is disposed between the first ground plate and the second ground plate.

11. The overlay EBG structure of claim **10**, wherein the plurality of plates are suspended above the substrate, the transmission line, the first ground plate and the second ground plate by the plurality of vias.

12. The overlay EBG structure of claim **11**, wherein the transmission line, the plurality of plates, the plurality of vias, the first ground plate and the second ground plate are disposed above the substrate on the same side of the substrate.

13. The overlay EBG structure of claim **11**, wherein an electric field is generated vertically between the plurality of plates and the first ground plate, and vertically between the plurality of plates and the second ground plate, when the signal is transmitted through the transmission line.

14. The overlay EBG structure of claim **1**, further comprising a first ground plate and a second ground plate disposed on the substrate such that the transmission line is disposed between the first ground plate and the second ground plate,

wherein each plate of the plurality of plates has a bottom surface comprising a first end portion, a second end portion and a center portion disposed between the first end portion and the second end portion,

each via of the plurality of vias is connected to the center portion of the bottom surface of one of the plurality of plates,

the first end portion of the bottom surface of each of the plurality of plates extends over, suspended above, the first ground plate such that a respective first air gap is formed therebetween, and

the second end portion of the bottom surface of each of the plurality of plates extends over, suspended above, the second ground plate such that a respective second air gap is formed therebetween.

15. The overlay EBG structure of claim **14**, wherein the signal is transmitted from the transmission line to the plurality of plates through the plurality of vias, and a respective electric field is generated vertically between the first end portion of the bottom surface of each of the plurality of plates and the first ground plate, and vertically between the second end portion of the bottom surface of each of the plurality of plates and the second ground plate.

16. The overlay EBG structure of claim **14**, wherein the plurality of plates are suspended above the substrate, the transmission line, the first ground plate and the second ground plate by the plurality of vias.

17. The overlay EBG structure of claim **16**, wherein the transmission line, the plurality of plates, the plurality of vias, the first ground plate and the second ground plate are disposed above the substrate on a same side of the substrate.

* * * * *